

RESEARCH PAPER

Prickly sida (*Sida spinosa* L.) and spurge (*Euphorbia hyssopifolia* L.) response to wide row and ultra narrow row cotton (*Gossypium hirsutum* L.) management systems

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A 4 year field study was conducted from 1998 to 2001 to evaluate the response of prickly sida (*Sida spinosa* L.) and hyssop spurge (*Euphorbia hyssopifolia* L.) growing in either ultra narrow row (UNR) or wide row (WR) cotton (*Gossypium hirsutum* L.) management systems. Weeds surviving pre- and postemergence herbicide treatments were harvested just prior to defoliation and the morphological characteristics were compared. Prickly sida growth was significantly reduced with regard to the number of main stem nodes, primary, secondary and tertiary branching, number of seed capsules produced and dry weight under UNR compared with WR. However, plant height was not affected by the management system. Spurge growth was significantly reduced with regard to branching and fresh weight but not height. These results show that UNR might suppress weed development by reducing vegetative and reproductive growth of prickly sida and vegetative growth of spurge. The reduction in seed and seed capsule production of prickly sida is likely to reduce its reproductive potential and also diminish the subsequent seed rain and soil seed bank reserves. Thus, a potential benefit of UNR cotton management systems might be to reduce the competitive ability of weeds and decrease seed production.

Keywords: hyssop spurge, prickly sida, ultra narrow row cotton.

INTRODUCTION

Advances in cotton (*Gossypium hirsutum* L.) production technologies in recent years have led to renewed interest in ultra narrow row (UNR) management systems as a way to improve profits (Gwathmey 1998). The UNR cotton has been defined as cotton grown in rows spaced at 25 cm or less (Atwell *et al.* 1996). The strategy behind UNR cotton is to increase plant populations and reduce row spacing so that the geometry of the plant population

is more evenly distributed. For example, at a row spacing of 25 cm and 250 000 seeds per hectare, plants are spaced approximately every 16 cm along the row. Typically, a wide row (WR) system contains approximately 100 000 seeds per hectare at a 100 cm row spacing with seeds every 10 cm apart. With a more evenly spaced plant population, the length and nodes on sympodial branches are reduced so that the plant produces a greater percentage of first position bolls (Atwell 1996; Kerby 1998; Jost & Cothren 2001). Furthermore, narrow row spacing with higher plant populations leads to a more rapid canopy closure because a greater number of smaller plants are growing in close proximity to each other (Jost & Cothren 2000).

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Delayed weed growth, reduced weed competition and better weed control is anticipated with narrower rows because the canopy develops much earlier, restricting light to weeds in the inter-row spaces (Pratley 1994). Reduced row spacing and increased seeding rates in

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soybeans have been shown to reduce sicklepod populations and seed production (Nice *et al.* 2001). In soybeans, weed resurgence, measured by weed density and weed biomass, increased as row spacing increased (Yelverton & Coble 1991). In snap beans, narrow rows suppressed weed growth by 18% over wide rows (Teasdale & Frank 1983). However, if weeds were controlled for the first half of the season, the weed suppression effect of snap bean row spacing increased from 18 to 82% (Teasdale & Frank 1983). Reductions in weed stem diameters, biomass, fruit load and seed formation have been documented as a result of increased shading (Stoller & Myers 1989; Benvenuti *et al.* 1994).

Little is known of the effects of UNR cotton management systems on weeds. However, studies on UNR cotton have shown that by 61 days after planting UNR cotton reached 93% canopy closure whereas canopy closure in wide row cotton was only 32% (Jost & Cothren 2000). In the UNR cotton management system with 25 cm rows, weeds would be less than 12.5 cm from the crop whereas weeds could be up to 50 cm from the crop in 100 cm rows. Thus, a different subcanopy environment resulting from increased shading and perhaps increased competition for resources under UNR conditions might provide benefits in weed suppression similar to that observed in other crops. The early canopy closure in UNR cotton might even reduce the need for late season weed control (Snipes 1996).

Prickly sida (*Sida spinosa* L.) and spurge (*Euphorbia hysopifolia* L.) are two weeds commonly found competing with cotton throughout a season in southern US, and both may achieve heights equal to or greater than cotton. Although both are easily controlled with herbicides, those that escape treatment emerge with or after cotton, or after canopy closure, might grow to a size that reduces harvest efficiency and lint quality, and can re-infest fields. For example, spurge reduced cotton dry weight, the number of bolls and the yield (Bararpour *et al.* 1994), whereas prickly sida reduced the yield by 40% in high populations (Buchanan *et al.* 1978, 1980). An unfortunate consequence of UNR management systems is that early canopy closure and narrow rows prevents post-directed herbicide applications. Thus, weeds surviving early season herbicide treatments and growing within the canopy might achieve a size that is unresponsive to post over-the-top treatments when they emerge through the canopy.

The objectives of the present study were to describe the effects of UNR and WR cotton management systems on phenotypic growth responses of prickly sida and spurge

in order to define the potential benefits of row spacing and plant population modifications to further more effective or sustainable weed management.

MATERIALS AND METHODS

The present study was conducted from 1998 to 2001 at the USDA-ARS Southern Weed Science research farm in Stoneville, MS, on a Dundee silt loam (fine-silty, mixed thermic Aeric ochraqualf) soil with pH 6.8, 1.2% organic matter, a cation exchange capacity (CEC) of 15.5 meq/100 g, and soil textural fractions of 25% sand, 56% silt and 19% clay. The experimental area was naturally infested with prickly sida and spurge. Each fall, the experimental area was prepared by disking, subsoiling and hipping into beds. The beds were harrowed to a height of 10–15 cm. Potash containing sulfur was applied each fall at rates of 224 and 3.36 kg ha⁻¹, respectively. In the spring, 100 kg ha⁻¹ of nitrogen as urea ammonium nitrate were applied in furrows 1 month prior to planting. The experimental area was treated with paraquat at 1.12 kg ha⁻¹ 2 weeks before planting. Glyphosate-tolerant cotton cultivar, DP 436RR, was planted on 8 May 1998, 23 April 1999, 22 May 2000, and 26 April 2001. The UNR cotton was planted with a Monosem NG Plus precision planter (Monosem ATI, Inc., Lenexa, KS, USA) in 25 cm rows at a density of 308 882 seeds ha⁻¹. The WR cotton was planted with a JD7300 air planter (Deere and Co., Moline, IL, USA) in 100 cm rows at a density of 100 000 seeds ha⁻¹. Pendimethalin and flumeturon were applied as a tank mix at 0.8 and 1.12 kg ai ha⁻¹, respectively, immediately after planting. Two glyphosate applications, each at 1.12 kg ae ha⁻¹, were made post-emergence at the first and fourth leaf stage of cotton development. A standard pest management program for the Delta was followed to control insects (Reddy 2001). Mepiquat chloride was applied to the UNR cotton at the 10 node and 14 node stages at 31 g ha⁻¹ for defoliation. Experimental plots were 90.2 m long and either in 32 rows spaced 25 cm apart or eight rows spaced 100 cm apart. The experiment was conducted in a randomized complete block design with three replications. Pre-emergence herbicides were applied with a tractor-mounted sprayer with Teejet 8004 flat fan tips calibrated to deliver 187 L ha⁻¹ water at 179 kPa. Postemergence herbicide and mepiquat chloride treatments were applied with a JD 6000 sprayer with Teejet 8004 flat fan tips calibrated to deliver 187 L ha⁻¹ water at 179 kPa. Insecticides were applied with a JD 6000 sprayer (Deere and Co., Moline, IL, USA) with Teejet TX-6 cone tips calibrated to deliver 36 L ha⁻¹ water at 300 kPa.

Prickly sida and spurge plants were harvested mid-August from both UNR and WR cotton plots by cutting the stem at the soil surface. To evaluate the maximum growth potential of the weeds, the three largest plants of each species, based on the dry weight, were evaluated. The maximum growth potential was evaluated as a first approximation of the competition between cotton management systems. Weeds showing maximum growth were those first to escape the herbicide treatments and having the longest growth period within the cotton canopy.

The parameters measured for spurge were the height, number of branches at median plant height and dry weight. The parameters measured for prickly sida were height, number of nodes, number of primary, secondary and tertiary, branches, number of seed capsules, total dry weight, main stem dry weight, branch dry weight and the node number of the position of the first branch. The weight-to-height ratio and percentage branch weight of the total weight were calculated.

The amount of light that permeated through the cotton canopy was measured when cotton reached a height of approximately 60 and 100 cm using a 100 cm long Line Quantum sensor (Li-Cor, Lincoln, NB, USA). Measurements were made in 2000 and 2001 within an hour of solar noon on calm, cloud-free days. Above the canopy the light intensities were 1725 and 1714 $\mu\text{mol m}^{-2} \text{s}^{-1}$, respectively, for 2000 and 2001. The line sensor was placed on the soil surface perpendicular to the row with the edge beginning at the crop row (from top center to the top center of neighboring beds). In the WR system, the sensor spanned the distance between two rows, and in the UNR system, the sensor spanned 4 rows. Five determinations were made per plot.

The data were subjected to analysis of variance using Proc GLM to determine the significance of the main effects and the interactions among the main effects (SAS 2002).

RESULTS AND DISCUSSION

The estimates of the effects of the cotton management system on weed characteristics for the weeds exhibiting maximal growth showed there was significant year by treatment interactions, except for height. Therefore, data were not combined over years. Prickly sida height was not affected by the cotton management system, (Table 1) except in 2000, and the effect of the cropping system on weed height was inconsistent over the 4 years. Cotton heights at the time of the weed harvest were 79.2, 77.0,

Table 1. Effects of cotton management system on height, main stem dry weight and weight-to-height ratio of prickly sida

	Height (cm)				Main stem dry weight (g plant ⁻¹)				Weight-to-height ratio						
	1998	1999	2000	2001	Mean	1998	1999	2000	2001	Mean	1998	1999	2000	2001	Mean
Management system															
WR	89.7a	97.8a	111.3a	85.7a	96.3a	20.3a	8.2a	7.7a	6.5a	10.8a	0.25a	0.50a	0.51a	0.47a	0.43a
UNR	95.1a	113.1a	84.8b	79.7a	93.2a	12.3b	5.9b	2.7b	2.0b	5.7b	0.09b	0.15b	0.22b	0.21b	0.17b
Source of variation			ANOVA					ANOVA							ANOVA
Management system			NS					***							***
Year			***					***							***
Management system × Year			***					NS							*

Within columns, means followed by the same letter are not significantly different ($P > 0.05$). ANOVA, analysis of variance; NS, not significant ($P > 0.05$); UNR, ultra narrow row; WR, wide row. * $P < 0.05$. *** $P < 0.0001$.

81.9 and 82.5 cm for WR and 56.4, 68.8, 63.6 and 69.6 cm for UNR over the 4 year period, which indicates that weed height exceeded crop height. Plant height is perhaps less sensitive to cotton management systems, especially when weeds emerge with the crop. There was a significant decrease in the main stem dry weight in the UNR management system compared to the WR without a reduction in height (Table 1). The weight to height ratios (Table 1) revealed that stems from WR had a greater mass per centimeter of growth than the UNR system. Considering the decrease in main stem dry weight, these data indicate that stem diameter was reduced by UNR, although this characteristic was not measured. The results presented here differ from those of Benvenuti *et al.* (1994), who reported that the height of three weed species increased in response to shading, and stem diameter either decreased or was not affected by shading depending on the species. In studies on the effects of shading on plant height, Nice *et al.* (2001) also showed that sicklepod height increased approximately 25% when a shading regime between 47 and 80% was imposed. Hence, prickly sida has different responses in height to competition than other weeds.

Total plant dry weight and branch dry weight were also very responsive to the cotton management system and both were reduced in all years under UNR conditions compared with WR (Table 2). A decrease in weed biomass has been correlated with a decrease in row spacing (Wax & Pendleton 1968; Yelverton & Coble 1991; Malik *et al.* 1993), with proximity to the crop row (Buchanan *et al.* 1980; Stoller & Myers 1989; Smith & Jordan 1993) and with shading (Benvenuti *et al.* 1994; Nice *et al.* 2001). The decreases in prickly sida and spurge biomass with the UNR management system could be the result of interference due to increased shading created by the combined effects of decreased row spacing and a higher plant population. The amount of light permeating through the UNR system to the soil was decreased by more than 70% compared with the WR system (Table 3) when cotton was approximately 60 cm, and light permeation decreased further when cotton height increased to 100 cm. However, the extent that the increased cotton density in UNR limits the availability of other resources, such as water and nutrients, to weeds is not known and such effects cannot be excluded from the interpretation of results. Expressing the branch dry weight as a percentage of the total dry weight showed that the UNR management system reduced allocation of carbon into the branch dry matter (Table 2).

The number of primary, secondary and tertiary branches and the number of seed capsules of prickly sida were all

Table 2. Effects of cotton management system on total dry weight, branch dry weight and percentage branch/total dry weight of prickly sida

	Total dry weight (g plant ⁻¹)					Branch dry weight (g plant ⁻¹)					Branch/Total dry weight (×100)				
	1998	1999	2000	2001	Mean	1998	1999	2000	2001	Mean	1998	1999	2000	2001	Mean
Management system															
WR	220a	58a	35a	33a	88a	199.7a	49.8a	27.3a	26.5a	77.2a	90.5a	85.4a	78.1a	79.4a	83.4a
UNR	56b	12b	6b	4b	19b	43.7b	6.1b	3.3b	2.0b	13.7b	74.7b	49.9b	48.9b	52.7b	56.5b
Source of variation															
Management system			ANOVA					ANOVA					ANOVA		
Year			***					***					***		
Management system × Year			***					***					***		
			***					***					*		

Within columns, means followed by the same letter are not significantly different ($P > 0.05$). ANOVA, analysis of variance; UNR, ultra narrow row; WR, wide row. * $P < 0.05$; *** $P < 0.0001$.

Table 3. Effects of cotton management system on light penetration through the canopy

	Light penetration ($\mu\text{mol m}^{-2} \text{s}^{-1}$) (% of above canopy light intensity)					
	Cotton height 60 cm			Cotton height 100 cm		
	2000	2001	Mean	2000	2001	Mean
Management system						
WR	1107a (64.2)	714a (41.7)	911a (53.0)	142a (8.2)	309a (18.0)	228a (13.3)
UNR	295b (17.1)	211b (12.3)	253b (14.7)	41b (2.4)	58b (3.4)	49b (2.8)
Source of variation		ANOVA			ANOVA	
Management system		***			***	
Year		***			**	
Management system \times Year		**			**	

Within columns, means followed by the same letter are not significantly different ($P > 0.05$). ANOVA, analysis of variance ($P > 0.05$); UNR, ultra narrow row; WR, wide row. ** $P < 0.01$. *** $P < 0.0001$.

reduced in UNR compared with WR (Table 4). The actual number of primary branches was less for prickly sida from UNR cotton, which subsequently resulted in fewer secondary and tertiary branches. Tertiary branches were not produced in prickly sida from UNR in the 4 years of study. These results show that reduced branching was a primary response to the UNR cotton management system. Loss of lower primary branches could greatly impact secondary and tertiary branch formation as well as seed capsule formation (Table 5) because these lower positions have greater time to develop throughout the season. The reduction in seed capsule production would most likely reduce seed rain and contributions to the soil seed populations. Stoller & Myers (1989) reported that shading reduced *Solanum ptycanthum* berry production. In addition, Benvenuti *et al.* (1994) found that shading reduced the number of fruits and thus decreased the seed production of velvetleaf, jimson weed and Johnson grass. The seed number per capsule was approximately five in both UNR and WR indicating that there was no effect of the cotton management system on seed production per capsule (data not shown). Germination studies on the seed from both cotton management systems failed so it is not known whether the cotton management system impacted on seed viability.

The number of main stem nodes (Table 5) decreased in all years for prickly sida from UNR cotton. The node number provides an estimate of the potential number of primary branches. Furthermore, the node position of the first branch (Table 5) was approximately 4–5 nodes higher in UNR than for prickly sida from WR cotton

showing that lower branch development was suppressed. A decrease in the number of positions of the lower branches of sicklepod (Smith & Jordan 1993) and of cocklebur, jimsonweed and velvetleaf (Regnier & Stoller 1989) was found for these weeds in soybean, and the position on the weed stem was strongly influenced by their relative position to the soybean canopy. Weed survival in these cases might have been dependent on the development of the upper canopy.

Growth reductions in spurge in response to the UNR cotton management system were similar to prickly sida (Table 6). As with prickly sida height, spurge height was similar for WR and UNR, although the mean height of spurge from UNR was significantly less in 1998 and 2001. In UNR, the spurge dry weight and number of branch axes at median plant height were reduced by more than 65% in each year (Table 6).

The results presented here show that UNR management systems reduced weed growth for certain weeds. Similar growth reductions might be expected for prostrate weeds, such as *Euphorbia maculata*. However, we have observed that in weeds that achieve heights greater than cotton, such as *Sesbania exaltata* and *Sorghum halepense*, growth was unabated in the UNR systems. There might be several other advantages of these systems even though growth reduction was not universal. For example, Smart (1993) showed that reduced herbicide levels could be used with 76 cm narrow rows while maintaining weed control. Hence, the efficacy of pre- or postemergence herbicides might be increased in

Table 4. Effects of cotton management system on primary, secondary and tertiary branches per plant of prickly sida

	Primary branches (plant ⁻¹)				Secondary branches (plant ⁻¹)				Tertiary Branches (plant ⁻¹)						
	1998	1999	2000	2001	Mean	1998	1999	2000	2001	Mean	1998	1999	2000	2001	Mean
Management system															
WR	30.7a	34.4a	29.6a	24.6a	29.6a	152.7a	146.4a	78.3a	37.3a	109.3a	110.0a	10.9a	2.1a	0.4a	29.8a
UNR	27.6a	21.1b	18.9b	13.8b	20.4b	56.0b	32.6b	3.7b	6.9b	24.9b	0b	0b	0b	0b	0b
Source of variation															
Management system			ANOVA					ANOVA					ANOVA		
Year			***					***					***		
Management system × Year			***					***					***		
			*					**					***		

Within columns, means followed by the same letter are not significantly different ($P > 0.05$). ANOVA, analysis of variance; UNR, ultra narrow row; WR, wide row. * $P < 0.05$. ** $P < 0.001$. *** $P < 0.0001$.

Table 5. Effects of cotton management system on the number of capsules, primary nodes and node position of first branch of prickly sida

	No. capsules (plant ⁻¹)				No. primary nodes (plant ⁻¹)				Node position of first branch						
	1998	1999	2000	2001	Mean	1998	1999	2000	2001	Mean	1998	1999	2000	2001	Mean
Management system															
WR	1321a	1546a	240a	105a	817a	44.5a	42.1a	36.1a	30.6a	38.1a	1.4a	1.4a	1.0a	1.4a	1.5a
UNR	374b	332b	66b	10b	142b	40.6a	36.6b	20.4b	23.9b	31.9b	6.3b	7.4b	7.6b	6.5b	7.1b
Source of variation															
Management system			ANOVA					ANOVA					ANOVA		
Year			***					***					***		
Management system × Year			***					***					NS		
			***					NS					NS		

Within columns, means followed by the same letter are not significantly different ($P > 0.05$). ANOVA, analysis of variance; NS, not significant ($P > 0.05$); UNR, ultra narrow row; WR, wide row. ** $P < 0.001$. *** $P < 0.0001$.

Table 6. Effects of cotton management system on height, total dry weight and branch axes at median plant height of spurge

	Height (cm)				Total dry weight (g plant ⁻¹)				Branch axes at median plant height (plant ⁻¹)						
	1998	1999	2000	2001	Mean	1998	1999	2000	2001	Mean	1998	1999	2000	2001	Mean
Management system															
WR	128a	111a	124a	89a	111a	481.2a	63.4a	60.1a	20.4a	147.6a	85.7a	288.1a	209.2a	20.7a	157.9a
UNR	110b	109a	128a	81b	109b	150.0b	9.5b	19.4b	3.3b	35.4b	30.2b	55.1b	60.3b	2.8b	47.5b
Source of variation															
Management system			ANOVA					ANOVA					ANOVA		
Year			***					***					**		
Management system × Year			NS					***					***		
			**					***					**		

Within columns, means followed by the same letter are not significantly different ($P > 0.05$). ANOVA, analysis of variance; NS, not significant ($P > 0.05$); UNR, ultra narrow row; WR, wide row. *** $P < 0.001$. ** $P < 0.0001$.

UNR systems allowing for application of reduced rates or delayed application. Furthermore, the critical weed free periods of crops might be altered in UNR systems as well as the time of herbicide application to achieve the necessary weed-free period. In addition to effects on herbicide efficacy, the environment under dense crop canopies produced in UNR systems might alter weed seed survival and seed bank dynamics, and perhaps increase weed susceptibility to seeding diseases. If weed populations can be skewed to those having less growth and fewer seed capsules by alterations in the management system, then row spacing and plant population modifications should be considered as a means to increase weed management sustainability.

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